

FELL AND BURN TO REGENERATE MIXED PINE-HARDWOOD STANDS: AN OVERVIEW OF RESEARCH ON STAND DEVELOPMENT

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Abstract.—The fell-and-burn site preparation technique has been used successfully on the Sumter National Forest in the mountains of South Carolina to regenerate poor-quality stands to productive pine-hardwood mixtures. Young stands typically have numerous hardwood sprouts, but growth and survival of planted pines are excellent. Despite this success, many questions remain. The Southeastern Forest Experiment Station is studying this and other techniques to establish pine-hardwood mixtures in the Piedmont. In this region, variations in the fell-and-burn technique may be required due to differences in species composition and site. Burning prescriptions must be developed to protect the thin root mats. Growth and yield are being projected for mountain and Piedmont sites.

INTRODUCTION

Because demands for softwood and hardwood timber are increasing in the Southeast, forest managers and researchers are searching for profitable methods to increase forest productivity. One alternative is to place poorly stocked, unmanaged forest lands under some form of management. The Piedmont and mountain regions of the Southeastern United States have 39.5 million acres of commercial forest land. Over 65 percent of this timberland (26.8 million acres) is occupied by hardwood or mixed pine-hardwood stands (Bechtold and Ruark 1988). Private nonindustrial landowners, who control 72 percent of these stands, usually do not manage their woodlands.

Since hardwood competition is vigorous in these regions, conversion to stands of pure pine requires extensive site preparation. Most landowners have chosen to leave their forests unmanaged rather than spend the \$150 to \$250 per acre required for reforestation. The result has been a large acreage of poorly stocked stands with large numbers of undesirable stems. To encourage private landowners to manage their forests, low-cost alternatives for site preparation must be developed along with projections of future yields and returns on investments.

A less expensive alternative to pine plantation management is the culturing of pine-hardwood mixtures. A low-cost site preparation technique, called fell and burn (Abercrombie and Sims 1986), has been successful in the Southern Appalachian Mountains for converting low-quality hardwood stands to productive pine-hardwood mixtures. On the Sum-

ter National Forest in South Carolina, over 3,500 acres on mountain sites have been converted by the fell-and-burn technique over the past 9 years. For less than \$100 per acre, including site preparation and planting costs, hardwood sprout growth is controlled enough to allow shortleaf pine (*Pinus echinata* Mill.) seedlings to become established and grow (Phillips and Abercrombie 1987). In three randomly selected 4-year-old stands, survival of free-to-grow shortleaf pine seedlings was generally over 75 percent. Hardwood sprouts were numerous, but they were generally less than 6 feet tall, while planted shortleaf pines averaged over 8.5 feet tall.

The success of the fell-and-burn technique is apparent in young stands on the mountains of the Sumter National Forest. However, many questions remain, including application to new regions, the need for intermediate treatments, and stand growth and yield. This paper presents an overview of research being conducted by the Southeastern Forest Experiment Station's Research Work Unit for the Silviculture and Management of Pine-Hardwood Mixtures in the Piedmont (SE-4105). Silvicultural techniques proven in the Appalachian Mountains will be tested in the Piedmont, and growth and yield of the new mixed stands will be projected.

THE FELL-AND-BURN TECHNIQUE

The fell-and-burn technique was described in detail by Abercrombie and Sims (1986), Phillips and Abercrombie (1987), and Van Lear and Waldrop (1988). Briefly, the technique involves clearcutting of hardwood or pine-hardwood stands and chain-saw felling of standing residual stems over 5 feet tall in mid-April to early June. At this time in the Southern Appalachian foothills of South Carolina, most trees are three-quarters to fully leafed out. Timing is critical because the dried leaves and twigs

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are needed as fuel to carry a summer broadcast burn. Also, sprout vigor is reduced by cutting when carbohydrate reserves in root stocks are in low supply. When trees are cut after they have leafed out, twigs and small branches dry more quickly through transpirational drying (McMinn 1986) and the depletion of hardwood carbohydrate reserves helps pines that will be planted later to compete for growing space.

Broadcast burns are conducted 4 to 6 weeks after residual stems are felled, generally in mid-July to early August. The desired burn is a high-intensity fire over a moist fuel bed. Burning is generally conducted 1 to 3 days after a soaking rain when the moisture content of 10-hour timelag fuels (1/4 to 1 inch in diameter) is 10 percent. At that time, the felled stems have sufficiently dried to carry an intense fire but the forest floor and surrounding stands are too moist to burn. This timing ensures that only a portion of the forest floor will be consumed, leaving a protective cover over the mineral soil. Guidelines for broadcast burning safely and effectively in the Southern Appalachians are discussed by Danielovich and others (1987). During the winter following burning, improved shortleaf pine or loblolly pine (*P. taeda* L.) seedlings are planted on a 10- by 10-foot spacing.

During 1988, the total cost of regenerating by the fell-and-burn technique was \$88 per acre. Contracts for chainsaw felling averaged \$35 per acre. Broadcast burning was conducted by the South Carolina Forestry Commission for \$9 per acre. Planting contracts averaged \$27 per acre, while the cost of seedlings was \$17 per acre.

Summer broadcast burning is probably the more beneficial of the two steps in this site-preparation technique. Sprouts that develop after chainsaw felling are top-killed by the fire and new sprouts are less vigorous. Burning removes over 65 percent of the woody fuels less than 3 inches in diameter (Sanders and Van Lear 1988), making the site more accessible for planting. After planting, the black surface makes green seedlings more visible, ensuring a better job of planting. The fire also kills aboveground buds on hardwood stumps, forcing new sprouts to originate from below ground (Augspurger and others 1987). Therefore, these new sprouts will be well anchored and of better form.

In trials of practical scale, broadcast burns removed 80 percent of the surface forest floor, but 67 percent of the root mat remained intact (Danielovich 1986). This root mat is important for its water holding capacity. It acts as a mulch, allowing young pines

to survive and grow. The root mat also helps prevent erosion. Van Lear and Danielovich (1988) found that erosion, measured as trapped sediment, did not increase in clearcut and burned areas when compared to clearcut areas that were not burned. Lack of erosion following clearcutting and burning was attributed to large stems and stumps acting as debris dams; vigorous shrub and herbaceous regrowth; and burning under moist conditions so that the root mat remained intact. A summary of the effects of the fell-and-burn technique on Appalachian soils is given by Van Lear (1989).

To monitor growth and development of stands regenerated by the fell-and-burn technique, sample plots were installed in the oldest stands on the Sumter National Forest that were site-prepared by the fell-and-burn technique and planted with shortleaf pine and loblolly pine. To prevent ice damage, loblolly pine was planted on sites lower than 1000 feet above mean sea level while shortleaf pine was planted on sites above 1000 feet. Plots were inventoried during the winter of 1987. At that time, the oldest shortleaf pine stands were 6 years old and the oldest loblolly pine stands were 7 years old. From 7 to 10 sample plots, 1/20 acre in size, were established at random locations within each of two stands for each species.

Sites planted with shortleaf pine had over 7500 stems per acre, the majority of which (85 percent) were blackgum (*Nyssa sylvatica* Marsh.), red maple (*Acer rubrum* L.), and other hardwoods (table 1). Even though hardwoods were numerous, survival and growth of planted pines was excellent. Of the 436 seedlings planted per acre, 83 percent survived for 6 years and were free to grow. Planted pines averaged 9.4 feet in height while hardwoods were generally less than 6 feet tall.

Lower-elevation sites planted with loblolly pine were also dominated by hardwood sprouts (table 2). Of the 4,883 stems per acre tallied on study plots, 87 percent were hardwoods. However, pine survival and growth were excellent. Over 95 percent of the planted pines survived and were free to grow. In addition, 186 volunteer pines per acre were present. Planted and volunteer pines were taller than most hardwoods and on some plots a closed pine canopy was beginning to develop. Red maple sprouts were prolific and dominated the overstory on some plots.

CURRENT RESEARCH

In 1986, the Southeastern Forest Experiment Station established a Research Work Unit at Clemson, SC, entitled "Silviculture and Management of Pine-Hardwood Mixtures in the Piedmont". Two problem areas were identified. The first includes the development and testing of silvicultural techniques to establish pine-hardwood mixtures in the Piedmont.

Table 1.--Species composition and mean height by species for 6-year-old shortleaf pine stands regenerated by the fell-and-burn technique

Species	Stems/acre (pct)	Mean height (feet)
Planted shortleaf pine	362 (5)	9.4
Natural pines	194 (3)	7.0
Select oak ^a	539 (7)	5.6
Blackgum	3,108 (41)	5.1
Red maple	1,192 (16)	8.2
Other hardwoods	2,147 (28)	5.2
Total	7,540 (100)	

^a Scarlet oak (*Quercus ~~coccinea~~ Muenchh.*), southern red oak (*Q. ~~falcata~~ Michx.*), white oak (*Q. alba L.*), post oak (*Q. stellata Wangenh.*), black oak (*Q. velutina Lam.*), chestnut oak (*Q. prinus L.*).

Table 2.--Species composition and mean height by species for 7-year-old loblolly pine stands regenerated by the fell-and-burn technique

Species	Stems/acre (pct)	Mean height (feet)
Planted loblolly pine	417 (9)	11.6
Natural pines	186 (4)	11.5
Select oak ^a	329 (7)	8.4
Blackgum	1,193 (24)	5.2
Red maple	1,414 (29)	9.5
Other hardwoods	1,324 (27)	6.9
Total	4,883 (100)	

^a Scarlet oak, southern red oak, white oak, post oak, black oak, chestnut oak.

Included in this problem area are studies of early stand development, intermediate treatments such as release and thinning, and effects of these treatments on vegetation, soils, and wildlife. The second problem area is designed to provide information on the productivity of pine-hardwood mixtures. Several approaches are being attempted to develop prediction models for stand growth and yield.

Due to the diverse nature of pine-hardwood mixtures and the fact that management of this type is relatively new, numerous topics have not been studied. The following discussion is an overview of some of the work being done by the Pine-Hardwood Research Work Unit on the fell-and-burn technique. It is not intended as an exhaustive review of research needs for pine-hardwood management.

Application in the Piedmont Region

Until recently the fell-and-burn technique had not been attempted outside of the Southern Appalachian Mountains. Due to differences in soils, topography, climate, and species composition, the technique may not work well in the Piedmont region. Variations of the technique or other site preparation methods may be necessary to establish pine-hardwood mixtures in this region.

A study, funded by the Georgia Forestry Commission, was begun in 1987 to test the fell-and-burn technique in the Piedmont. Study plots were established on the Dawson Forest in Dawson County, GA; the Clemson Experimental Forest in Pickens County, SC; and on private land in McCormick County, SC (figure 1). Selected sites were on

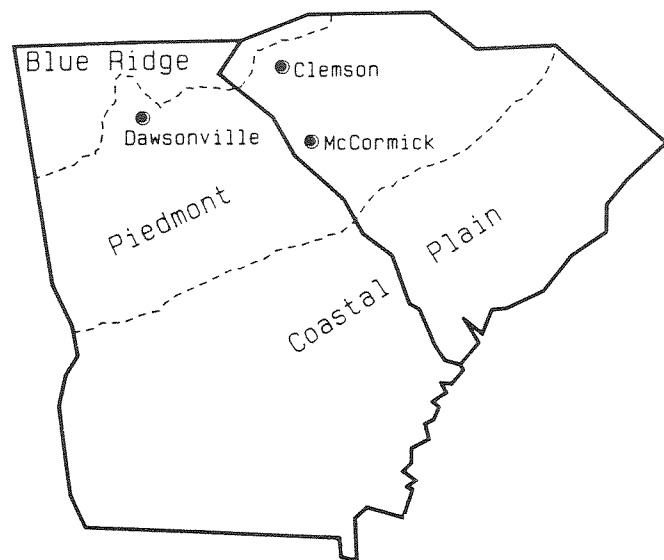


Figure 1.--Fell and burn to convert low-quality stands to productive pine-hardwood mixtures: Piedmont study sites.

predominantly south-facing slopes with stands dominated by scarlet oak (*Quercus coccinea* Muenchh.), southern red oak (*Q. falcata* Michx.), and hickories (*Carya* sp.). Clearcutting was completed during the winter of 1988. Chainsaw felling and broadcast burning were completed in May 1988 and July 1988, respectively. Loblolly pine seedlings were planted during February 1989. Rather than the usual 10 by 10 foot spacing, pines were planted on a 15 by 15 foot spacing (193 per acre) to allow hardwoods to compete and become a major component of the stand.

Three treatments were imposed in each of seven replications: fell and burn, fell only, and burn only. The fell only and burn only treatments were selected for two reasons. First, they are less expensive than felling and burning and may be attractive to private landowners. Second, they allow hardwoods a better chance to become a component of the stand. Loblolly pine is a vigorous competitor on many Piedmont sites, so the combination of felling and burning may not be necessary for pine survival. Since many landowners do not have the experience and resources to burn safely, the elimination of this step would be particularly attractive.

Early results of this study indicate several differences in applying the fell-and-burn technique in the Piedmont. Species composition of competing hardwoods is more variable than on the mountain sites of the Sumter National Forest. Study sites on the Clemson Experimental Forest are located in the Upper Piedmont and have many species similar to the Sumter National Forest (table 3). However, sourwood (*Oxydendron arboreum* L.) and dogwood (*Cornus florida* L.) are more numerous. Even though these species will not be major competitors in older stands, they may overtop planted pines in early years. McCormick County study sites are representative of the Middle Piedmont. The dominant species on these plots are sweetgum (*Liquidambar styraciflua* L.) and naturally-regenerated loblolly pine. Sweetgum sprouts prolifically and grows rapidly. Both felling and burning may be required to control sweetgum growth enough to allow pines to compete.

Broadcast burning may damage Piedmont sites. Because of the history of farming on Piedmont sites, root mats there are not as well developed as in the mountains. On the Sumter National Forest, root mats are often over 3 inches thick, while they were less than 1 inch thick on all Piedmont study plots. Strict burning guidelines must be developed to prevent soil exposure and erosion on Piedmont sites.

Two additional studies have been established in these study areas. One will document the effects of spring felling and summer broadcast burning on

Table 3.--Species composition of seedlings and sprouts on two Piedmont sites prior to planting.

Species	Clemson Forest	McCormick County
	----- Stems per acre (pct) -----	
Pines:		
Loblolly	---	2,133 (18)
Shortleaf	16 (<1)	---
Oaks:		
Scarlet	1,160 (10)	---
White	841 (7)	747 (6)
Black	827 (7)	---
Post	509 (4)	167 (1)
Other oaks	678 (6)	94 (1)
Other Hardwoods:		
Blackgum	1,678 (14)	233 (2)
Sourwood	1,665 (14)	---
Hickory	1,419 (12)	27 (<1)
Dogwood	1,984 (17)	---
Sweetgum	---	6,473 (55)
Miscellaneous	927 (8)	1,927 (16)
Total	11,704 (100)	11,774 (100)

sprout vigor. While these treatments are known to slow hardwood growth, the degree of reduction has not been documented. This study will provide insight into alternatives of the fell-and-burn technique that may be needed to allow pines and hardwoods to grow together. The other study will document the effects of the various treatments on the quality of habitat for several wildlife species. Detailed descriptions of the vegetation available for browse are being compiled. In addition, small mammals are being trapped to obtain an estimate of utilization.

Site Selection

Success in establishing pine-hardwood mixtures with the fell-and-burn technique depends on site selection. On sites of low productivity, hardwoods are generally absent or grow slowly and have poor form. Culturing quality hardwoods on these sites would be expensive or, in many cases, impossible. Highly productive sites, on the other hand, are best suited for hardwoods. Planted pines are quickly overtopped by vigorous hardwood sprouts. On the Sumter National Forest, the technique has been successful on medium sites—slopes with south to

southwest aspects and a site index of 65 to 70 feet for upland oaks at 50 years. No effort has been made to determine the upper and lower bounds of site quality for which pine-hardwood mixtures can be successful.

On many sites in the Southern Appalachian Mountains and Piedmont, existing stands are poor indicators of site quality. High-grading, fires, and mismanagement have produced low-quality stands on sites with high productive potential. To evaluate the potential of such sites for pine-hardwood management, a classification system based on factors other than standing trees is needed. A cooperative study has been established with Clemson University to develop an ecologically based classification system for the Piedmont using a technique proposed by Jones and others (1984) and Jones (1989). Under this system, site types are described as specific combinations of understory and overstory vegetation, land forms, and soil types. Site types suitable for pine-hardwood mixtures will be identified.

In the study of the fell-and-burn technique in the Piedmont, mentioned above, study plots were established on slopes with south and southwestern aspects. In five of the seven replications, however, sites ranged from dry upland ridges to moist north-facing slopes and coves. In each case, the entire

harvested area was prepared by the fell-and-burn technique. Additional study plots are being established in these stands on as many site types as possible. These plots will be used to validate the Piedmont site classification system and to gain insight into the relationship between site quality and the success of pine-hardwood regeneration.

Growth and Yield

Information on stand growth and yield is limited for pine-hardwood mixtures. The small amount of reported research has either viewed the hardwood component as a competing understory (Smith and Hafley 1987, Burkhardt and Sprinz 1984) or has focused on relatively short term projections (20 years or less) using inventory data from pine-hardwood stands in the Southeast (Meldahl and others 1988). As a result, permanent growth and yield plots are being established in the Piedmont to develop forecasting systems for pine-hardwood mixtures.

One study examined the ability of six mixed-species models developed for other regions to describe the development of young pine-hardwood stands on the Sumter National Forest. The models tested were SILVAH (Marquis and others 1984), OAKSIM (Hilt 1985), G-HAT (Harrison and others 1986), Central States TWIGS (Belcher 1982), GATWIGS (Meldahl and others 1988), and FORCAT (Waldrop and others 1986). All candidate models underestimated stem numbers over a 5-year simulation period (ages 2 to 7 in loblolly pine mixtures and 1 to 6 in shortleaf pine mixtures), primarily because stem numbers in young clearcuts typically increase for several years as sprouting increases and seedlings develop. Another problem dealt with the relative growth rates of hardwoods and planted pines. Hardwood vigor is reduced by the fell-and-burn technique (Geisinger and others 1989), making it easier for pine seedlings to compete with hardwood coppice regeneration. Each model predicted fast growth of hardwoods at the expense of pine growth and survival. None of these models was developed for young clearcuts in the Southern Appalachians or Piedmont, so poor model performance was not unexpected.

Formulation of forecasting predictors for early stand development (prior to crown closure) is important because change is rapid, and subtle differences in establishment conditions can dramatically affect the percentage of pines capturing a position in the overstory. Once crowns have closed, subsequent changes in species composition are slow and are the result of competition and self-thinning instead of the relative ability of species for rapid early height growth. As a result, a modeling approach is being developed on the principles that 1) there will be separate model components for pre-closure and

post-closure development stages which are driven by different inputs and linked by some measure of the size of the pine component at crown closure, and 2) both phases will be driven in part by height growth and built around a site classification system based on aspect, slope position, and depth to the maximum clay content (Jones 1989). Details of this modeling approach are presented by Lloyd (1989) elsewhere in these proceedings.

Fire Effects on Piedmont Sites

Site protection after the fell-and-burn technique depends largely on maintaining a thick root mat. This root mat protects the soil from erosion and acts as a mulch, retaining moisture for planted pines. Particularly on Piedmont sites, protection of the root mat is mandatory. Observations indicate that this mat is not as well developed on Piedmont sites, so the margin for error is slim. Little is known about the origin and distribution of root mats. Research is needed to determine the extent to which root mats occur in the Piedmont and the factors that influence their development.

Prescription guidelines have not been developed for broadcast burning on Piedmont sites. On the Sumter National Forest, fuel moisture sticks are used to determine when to burn. Generally, when these sticks contain 10 percent moisture, downed woody fuels are dry enough to burn but the forest floor and root mat are moist. When stick moisture content is below 10 percent, burning becomes risky. Fuel moisture sticks may prove useful on Piedmont sites, but they are untested. In addition, the relationship of fuel moisture, fuel type, weather, slope, and firing technique to fire intensity and fire severity must be established.

Scientists of the USDA Forest Service, the University of Georgia, and Clemson University have begun a cooperative research effort with the Agricultural Research Service in their Water Erosion Prediction Project (WEPP). WEPP is a nationwide program to develop a physical process-based model of surface erosion after disturbance to replace the Universal Soil Loss Equation. The initial research efforts in the Southeastern Piedmont are to study the effects of the fell-and-burn technique. A variety of sites will be burned by several firing techniques and at varying levels of fuel moisture to produce a range of fire severity. This work will determine how soil erosion and sediment production are influenced by rainfall, fire severity, soil properties, and slope. It will also provide preliminary data for developing guidelines for broadcast burning in the Piedmont.

SUMMARY AND CONCLUSIONS

Low-quality hardwood and pine-hardwood stands in the Southern Appalachian Mountains have been converted to productive pine-hardwood mixtures by the fell-and-burn technique. Since, the technique is inexpensive, it may attract private landowners to put their unmanaged stands into timber production. Introduction of pines to previously unmanaged hardwood stands improves stand value and increases management options while maintaining quality habitat for several wildlife species.

On sites at 1000 feet above mean sea level or higher, shortleaf pine is planted at a 10- by 10-foot spacing. These stands have numerous hardwood sprouts, but planted pines exhibit high survival and most are free to grow. At lower elevations, loblolly pine is planted. Even though these stands also have numerous hardwood sprouts, these sprouts are overtopped by the fast-growing pines within a few years. On these sites, a wider planting spacing or other refinements to the fell-and-burn technique may be necessary to allow hardwoods to compete with the pines.

The Southeastern Forest Experiment Station is studying several aspects of the fell-and-burn technique and pine-hardwood management. Research topics include application of the technique to Piedmont sites, site selection, growth and yield, and predicting fire effects. Many important questions remain. Once a pine-hardwood stand is established, for example, are intermediate treatments such as thinning or release needed? If so, how will growth and yield be affected? What products can be expected at various stocking levels and rotations? Can uneven-aged management techniques be used to establish pine-hardwood mixtures? How does the culturing of pines and hardwoods together affect wildlife habitat, water quality, and forest protection? As the fell-and-burn technique is refined and applied in new regions, it should prove useful in establishing pine-hardwood mixtures.

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